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STEREO CORRELATION SYSTEM

Prepared By:

[redacted]

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Approved By:

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Vice President - Engineering

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Extension of development effort for an Automatic Stereo Correlation System for use in 552 type Viewers.

The following proposal presents a plan to extend the development effort on an Automatic Stereo Correlation system that will be suitable for use in [redacted] type 552 or similar equipment. The proposal is divided into four sections. The first describes, briefly, the theory of operation of the [redacted] Stereo Correlation system. The second summarizes the results of the theoretical and experimental work performed under the development subcontract [redacted] The third section presents the specific plan proposed to continue development of the system with ultimate goal of developing a practical configuration compatible with the 552 design, and the fourth section describes, briefly, the method of integrating the Stereo Correlator with the 552 type design.

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I

THE AUTOMATIC STEREO CORRECATION SYSTEM

A. PURPOSE

The purpose of the system is to relieve an observer of stereo or puesdo-stereo images of the task of orienting the relative position, magnification, and brightness of the areas viewed to obtain a stereo effect. This eliminates operator fatigue and increases the speed at which films can be viewed and interpreted.

B. CORRELATION TECHNIQUE

The technique of automatically comparing and adjusting the position and size of two views of the same subject so that they may be viewed stereoscopically is basically as follows:

Consider first that the two images are identical, and there is no relative displacement. Each image is scanned by a narrow slit; the slits moving in synchronism, but one slit displaced in phase, or ahead. The brightness of the areas covered by the slits is converted to electrical signals by photo tubes. The images being identical, the signal patterns generated by the scanning slits should be identical but displaced in phase corresponding to the displacement of the slits. The absolute value of the difference of the two signals is taken, and its value integrated over the duration of the scan. The resulting value is a quantity whose magnitude is proportional to the displacement of the slits, and also proportional to the physical relative displacement of the images along the axis of the scan.

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This value is stored electronically for comparison with an integrated signal obtained on the second scan of the images. The second scan is similar to the first except the direction of displacement of the slots is reversed, the slot which was leading is now lagging. The difference between the two integrated absolute difference scan signal differences, is an indication of the magnitude and direction of the relative displacement of the images along the direction of scan. This signal is applied to a servo system to change the position of one image.

To better visualize what is taking place during the scanning of the images, consider a case of scanning two simple images (large dots), as is shown in Figure 1. As illustrated in Figure 1(a), the two images are identical and are in correspondence. The relationship of the two scanning slits is such that the slit of image b is leading in phase of that of a. In other words, the slit of b is slightly to the right of a. The signals developed by the scanning slits are shown. The difference of these signals is taken and the absolute value $\overline{(a-b)}$ is computed. The amplitude of a-b' is determined by changing the negative portion of the signal (a-b) to a positive value. Now, when the slit of image b' is lagging that of a', as shown in the lower right of Figure 2(II), then the slit of b' is slightly to the right of a'. The resultant signals of a', b', (a'-b') and $\overline{(a'-b')}$ are as shown.

It may be noted that in the case mentioned above, $\overline{(a-b)}$ for a leading slit phase is the same as $\overline{(a'-b')}$ for a lagging phase, or $\overline{(a-b)} - \overline{(a'-b')} = 0$.

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However, let us consider the case when the object in (b) is to the right of where it should be, as shown in Sections IV and V of Figure 2. Consequently, the two images are not in correspondence. It may be obvious that now that the difference $\overline{(a-b)}$ has decreased for the leading phase of the scanning slit, and has increased for the lagging phase. Consequently, if $\overline{(a-b)}$ leading is compared to $\overline{(a'-b')}$ lagging, then an error signal is developed corresponding to offset in the relative position of the object; consequently, $\overline{(a-b)} - \overline{(a'-b')}$ is negative as indicated in Section VI of Figure 2.

It may be noted that if the error of position of the object is reversed, as shown in Figure 2, (Section VII and VIII) then the difference $\overline{(a-b)}$ has increased for the leading phase, and has decreased for $\overline{(a'-b')}$ the lagging phase, then $\overline{(a-b)} - \overline{(a'-b')}$ is positive. Consequently, by comparing $\overline{(a-b)}$ leading to $\overline{(a'-b')}$ lagging, the polarity of the signal determines whether the error is to the right or to the left.

The operation of the system integrates the error $\overline{(a-b)}$ lead $- \overline{(a'-b')}$ lag. This integration is achieved by an R-C network, which averages the amplitude of the error. This DC signal is applied to a standard DC servo system, where the speed of the correction is dependent on the amplitude of the signal, and the direction of drive is dependent on polarity of the error signal.

Image correlation in the other axis is accomplished in a similar manner.

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Rotational alignment of the images is accomplished in basically the same manner. Again, the images are scanned by narrow slits along one axis. However, the phase leading and phase lagging signals are developed by angularly displacing the (b) slit in a clockwise and counterclockwise direction. This results in an $\overline{(a-b)}$ lead signal, which when compared with an $\overline{(a'-b')}$ signal results in a useable servo error signal.

Correlation of the sizes of the images (magnification) is accomplished again by a succession of simultaneous scans. However, the leading and lagging displacements of the slits are replaced by changing the image size at the plane of the slit, in one scan magnifying it slightly and in the second, minifying it slightly with respect to the reference image. The difference of the $\overline{(a-b)}$ and $\overline{(a'-b')}$ signals represents the error in relative magnification along the axis scanned.

The magnification correlating technique described above is suitable for adjustment of the relative size of the images based on the comparison of their size or magnification along one axis. If the images have an anomorphic error, that is if one image is stretched or compressed along one axis, it is eliminated by scanning an axis perpendicular to the magnification scan axis, detecting the error in magnification along that axis and servo driving an anomorphic lens.

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C. AVERAGING NATURE OF THE SYSTEM

The system design described has the very desirable feature of being an averaging sensor, whereby the two images do not have to be identical (such would be the case if the objects photographed had appreciable height). The system averages by scanning so that the signal developed by an offset in one direction $\overline{a-b}$ is always made to equal the signal produced by offset in the other direction $\overline{a'-b'}$. Consequently, if the contrast of the two images is not the same, there is always an optimum position where $\overline{a-b}$ and $\overline{a'-b'}$ are equal, even though the value of each may be relatively high. It may also be concluded that any distortion in one frame relative to the other does not cause malfunction of the system, due to this averaging feature.

D. THE AUTOMATIC CORRELATION SYSTEM DESIGN

A detailed description of the design has been presented in [redacted] "Final Report for Automatic Stereo Correlator [redacted] dated 23 July 1965, enclosed herein. The following is only a brief description.

The mechanization of the correlation method results in a mechanical and electronic design which is relatively simple. The scanning in all axes is accomplished by slots in a single rotating disc. The image formats are focused on the disc so that the format centers lie equidistant from the center and on a diametral line. The slots lie at angles of 45 degrees with respect to radials which produces the apparent linear translation of the scanning slit across the image in both axes. The scanning slits for each axis consist of a pair of slits located nominally 180 degrees apart. The exact position of the slits depends on their function; the X and Y pairs each less than 180 degrees apart, the θ pair are 180 degrees apart, but one slit is rotated slightly, and the slits for the magnification scan are 180 degrees apart, but one slit has mounted on the disc above it a lens which produces the magnification effect of displacement.

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The above is a greatly abbreviated description of the scanning mechanism, however, it should be apparent that the device is fundamentally simple, consisting basically of only one moving part, yet is capable of determining in a single revolution the relative X, Y, θ, and magnification errors of the two images.

The electronics too are very simple considering all the functions that they perform. This is accomplished to a great extent through the use of time sharing techniques. The photo-multiplier tubes, preamplifierds, difference amplifier and signal-to-amplitude converter are all time shared. The gates controlling the routing of signal data are controlled by photo-diodes activated by coded openings in the same scanning disc.

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II

SUMMARY OF RESULTS OF INVESTIGATIONS CONDUCTED UNDER CONTRACT [redacted]

The above reference effort consisted of basically, designing and constructing an experimental automatic correlation system to demonstrate the theoretical and practical feasibility of the correlation technique and to investigate some of the problems associated with incorporating this system with the 552 type film viewer. A detailed report, [redacted] Document [redacted] (previously referenced) on this contract was submitted in July 1965.

In short, a working experimental model, or breadboard was constructed and its ability to correlate simple images in position (X and Y), rotation (Θ) and magnification demonstrated. Linearity of error signals versus displacement was proven, and the ability of the system to work using a fiber optic cable and image enhancer (such as that used in the 552) was affirmed.

As was expected, a number of problems were encountered. Many of these were resolved, but a number require further investigation before a final design for a Correlator suitable for use with the 552 is decided upon. The major areas were:

A) Difficulty was encountered in the adjustment of the relative position of the scanning slits so as to obtain proper lead and lag signals. This problem was particularly acute when attempting to adjust the two pair of slits in each channel. The cause of this problem was the "breadboard" nature of scanning disc and its method of support.

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B) A problem area was recognized in the lack of rigidity in the mounts for the photomultiplier tubes.

C) The limited motion of the images possible before they exceeded the boundaries of the format, was a nuisance and required the use of only very small images.

D) The lack of linearity over a wide input ratio of the signal-to-amplitude converter limited the complexity of signals which could be processed.

E) There was a lack of signal sensitivity when the images were low contrast photographic negatives. This may very well have been due to the lack of sufficient range in the signal-to-amplitude converter.

The specific solutions to these problems and description of proposed further investigations is given in the next section.

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III

PROPOSED DEVELOPMENT EFFORT

The proposed development effort would be a continuation of the work done under [redacted] It would consist of making optical, mechanical, and electronic modifications to the existing experimental breadboard, conducting further tests and defining the essential design parameters for a correlation system suitable for integration with the 552 type viewer. It is proposed that the development extend over a 4-6 month period, and result in a final report and deliverable breadboard hardware. Monthly progress reports would also be submitted.

Specifically, it is proposed to make the following modifications to the experimental breadboard.

A) Change the mounting design of the scanning disc so that it may be readily removed for adjustment of the scanning slots.

B) Make a fixture for the accurate alignment of the scanning slots on the disc.

C) Change the design of the photomultiplier tubes mounts to a more rigid and accurate configuration.

D) Redesign the signal-to-amplitude converter to achieve a linear range of at least 150 to 1. This will consist of either using the present circuit with the substitution of transistors with especially good Betas at low signal levels and

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uniform threshold characteristics, or adopting an entirely different approach such as the use of a gallium arsenide light emitting diode, optically coupled to a silicon photo diode. This latter approach has the advantage in that the light emitter can be biased to eliminate threshold effects.

E) Redesign the circuitry and controls for image brightness. It was found that controlling image brightness by adjusting the voltage on the lamps resulted in too large a change in the color temperature.

F) Improve the mounting of the scan disc drive motor to eliminate vibration and noise.

G) Change the optics to allow a larger field of view and facilitate the optical alignment.

H) Modify Θ and M servo drives to obtain longer time constant.

In regard to experimental work, tests would be run to assess the performance and determine future design parameters. Among the tasks contemplated would be the following:

A) Conduct experiments to determine the relationship between images of various complexities and the correlation error signal outputs. This would include determining linearity, signal saturation point, noise content and complexity of image required for threshold response in each channel.

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B) Conduct experiments in conjunction with theoretical analysis to determine the effects of interaction between channels and to establish servo parameters to permit proper tracking. This will necessarily include an investigation of the dynamic performance in each channel and the determination of maximum useable tracking rates.

C) Devise a method by which the loss of a suitable tracking signal may be detected, so that the servos do not drift or run away.

D) Test different approaches for automatically controlling image brightness without appreciably changing color temperature.

E); Check effect of use of [redacted] Image En hancer on performance with complex targets. This would substantiate applicability of data gathered under [redacted] when using more complex targets.